IS THERE AN ALTERNATIVE TO THE TAYLOR RULE WHEN ESTIMATING A NEUTRAL REAL RATE OF INTEREST FOR THE EURO ZONE?

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In this paper Sophie Ward seeks to find a policy neutral interest rate which may be used for policy decisions. The issue of monetary policy is currently at its most important of the last few decades. The idea of having a 'neutral rate' around which policy can be based is an interesting one. It could have use as a benchmark to determine whether a chosen policy rate is likely to be expansionary or contractionary and be a judge of the extent. It defines an innovative type of economic policy whereby base rates may be set hoping to converge to this rate for maximal price stability. This might be particularly interesting now as there has been much debate over whether lax monetary policy was partially to blame for the crisis that we are currently trying to recover from. As this essay will consider, this neutral rate is not observable, so it must be estimated.

Introduction & Motivation

> " Government actions and interventions, not any inherent failure or instability of the private economy, government actions, caused, prolonged, and worsened the crisis" - John Taylor

The neutral real interest rate is, in essence, a medium term concept that indicates the level of real interest that is analogous with monetary policy that is cycle-neutral. It seems logical that such a 'real' rate be used as rational economic agents base decisions on real variables, not nominal ones. Our task will be to break down the nominal interest rate into parts that allow this neutral real rate (NRR) to be determined. There are many factors that may affect the economy other than monetary policy.

This question is best approached by estimating a model for the neutral rate, which I shall call the 'NRR Model', and also a more general model for the determination of the nominal interest rate, which I shall call the 'Determination Model'.

Literature thus far estimates this rate using a standard 'Taylor' framework, and for single countries, rather than a zone of monetary union such as the European Union. Such papers relate especially to the Federal Reserve, the Bank of Canada and the Reserve Bank of New Zealand.

The Theoretical Concept of NRR

The grounds of a theory begin by thinking about how we can tell if the base rate set in monetary policy is too high or too low. We have already mentioned that such a judgement may be made by virtue of a 'real interest rate' deducted for all nominal and cyclical factors. The simplest decomposition of a nominal interest rate comes from Fisher's Equation: $i = r + \pi^e$ *where i is the nominal interest rate, r is the real interest rate and* π^e *is expected inflation.*

We will find this expression to be useful in specifying our model. However, the *r* in the Fisher equation is cyclical, which will not answer our question. The nominal interest rate is one that the central bank, in this case the European Central Bank, may directly control. We will be using two nominal interest rates in our discussion, each for a different use. The three-month interbank rate will be used as a proxy for the nominal interest rate (dependent variable) in our Determination Model. The ECB's base money market interest rate will act as the dependent variable in the NRR Model. This rate is used for leaning in monetary policy.

The intuition behind this research is that the nominal interest rate may be decomposed thus:

Observed Nominal Interest Rate →

Ex-ante Real Interest Rate →

NRR →

Fundamentals affecting saving and investment decisions	Impediments to international capital flows	Country specific risk premia	Cyclical factors- the monetary policy lean	Expected inflations

Our aim will be to estimate the NRR by finding variables to fill the 'cyclical factors' mentioned in the scheme above.

Variables and Empirics

We estimate Taylor's Rule for the euro zone before trying to estimate a more 'all-encompassing' model for the NRR. Taylor estimated, without the use of econometrics, the following: $i = 2.5 + \pi + 0.5(\pi - \pi^*) + 0.5(y - y^*)$ *where 2.5 is the NRR,* $(\pi - \pi^*)$ *is the inflation gap between* *actual inflation and the target inflation rate set by monetary policy and (y – y*) is the output gap between actual output and potential output.*

Given that the ECB is known to be hawkish in its monetary policy we will expect the coefficient on the inflation gap to be higher than 0.5.

Models: In estimating the NRR Model, we will consider the following:

$$i = r + \beta_1(INFGAP) + \beta_2(GDPGAP) + \beta_3(STOXX) + \beta_4(SDR) + \beta_5(EMP) + u_i$$

Where i is the base rate, r is the NRR, INFGAP is the inflation expectation gap, GDP is the GDP growth gap, STOXX is a proxy for the performance of financial markets and SDR is a proxy for the exchange rate.

The mean of the constant and residual that result from such a regression may be taken as an indication of the neutral real rate. This is a reasonable assumption to make given that we are effectively stripping out the 'scheme-superfluous' nominal and cyclical components. The remainder of the model should be 'unexplained', and thus an indication of the NRR. In order to form a Determination Model, we will consider this:

$$i = \beta_0 + \beta_1(INF) + \beta_2(GDP) + \beta_3(STOXX) + \beta_4(SDR) + \beta_5(EMP) + \beta_6(logBANKRATE) + u_{ii}$$

The models themselves are to be run as a longitudinal cross-section. When estimating this rate, we are not especially concerned about the impact of a time series. We are more interested in defining a post-currency-union measure of the NRR for use in judging monetary policy. The years sampled are 1999 – 2007, and only the countries in the union from 1999 are included for simplicity's sake.

Variables: Each of the variables mentioned in the models above has a related discussion.

i (Bank Rate) - This is the rate that the ECB sets as its baseline money market rate. It will be useful in the NRR Model.

i (Nominal Rate) - This is the three month interbank rate for respective countries. It can be used when a Determination model is being estimated.

INF - This is the inflation for each country of the euro zone in terms of the HCIP, the harmonised consumer price index, as available from EuroStat. We would expect inflation to have an upward effect on the nominal interest rate. There should be no effect on the NRR.

INFGAP - This is the inflation expectation gap. It is taken as the difference between the actual level of inflation and the expected rate. We assume a basic 'static expectations' model, whereby the expected level of inflation for a given date is the actual inflation rate from the one before it.

GDP - This is taken as the growth in GDP from the previous year. When GDP increases we would expect the nominal rate to increase due to upward pressure on the cyclical component of the model.

GDPGAP - This is taken as the difference between the actual GDP growth rate, and an average of growth rates over the periods used.

STOXX - This is the percentage change in domestic stock indices from the previous year to get an idea of how financial markets have performed. We would expect a negative relationship between increasing stock indices and the nominal interest rate, as investment demand decreases when the interest rate increases.

SDR - This is the exchange rate against the IMF's special drawing rights. It allows a fair comparison. It is not clear whether there will be any relationship here, other than that if the exchange rate is favourable to inward capital flows we would expect the interest rate to adjust downwards in an arbitrage fashion.

EMP - This is the level of unemployment for respective countries. We would expect that if employment is high, the economy is operating with a positive output gap and that the interest rate would be raised in order to prevent over-heating in the economy.

All macroeconomic data (GDP, EMP & SDR) was obtained from the EuroStat website. The exchange rate data against special drawing rights came from the International Monetary Fund. Historical stock indices were obtained separately for each country from their respective central banks' websites and from Yahoo Finance.

Specifications and Results

The Taylor Rule was estimated first. The model that Taylor presented was not estimated econometrically, and it was found that to use both the inflation rate and the policy inflation gap was detrimental for the model owing to issues of collinearity. We find, in fact, that for the Euro Zone, Taylor's idea of the inflation gap is insignificant. This leaves us with a good lesson for producing a better NRR Model. We find that the best dependent variable is a log transformed bank set rate, given tests for heteroskedasticity.

$$i = 2.594 + 1.14(\pi - \pi^*) + 3.93(y - y^*)$$

After performing the 'mean' calculation for NRR.

Log Bank Rate raw

Inflation expectations gap	1.143 (2.171)	Observations	99
Output gap	3.933 *** (0.999)	Adjusted R-squared	0.139

Standard errors in parenthesis. * significant at 10%; **significant at 5%; ***significant at 1%.

Given the hawkish reputation of the ECB, we are not surprised that our coefficient for the inflation gap does not match Taylor's 0.5. The coefficient for the output gap is not especially interesting given that contemporary monetary policy is not primarily focussed on GDP growth rates. This model contends that if the inflation gap were to increase by 1 unit, then we would expect the base rate to be raised by 1.14%. We do agree, however, that the NRR for the Euro Zone is around Taylor's 2.5%.

The NRR Model

Having deduced that Taylor's Rule cannot come up with a reliable indicator of the NRR for significance reasons, we attempt to find a statistically sound model for the NRR by decomposition of the cyclical gap.

The NRR Model was estimated repeatedly using both *i(Bank Rate)* and *i(Nominal Rate)* and various combinations of the explanatory variables until the best model was obtained, in terms of both the goodness of fit and significance. Each variable underwent tests for linearity and normality and it was found that decimalised rates produced the best specification for the model, and that the only variables that were better transformed were the two nominal interest rates, which were logged.

$$\log i(\text{BANKRATE}) = 2.34 + \underset{(2.49)}{8.57}(\text{INFGAP}) + \underset{(0.98)}{2.89}(\text{GDP})$$

Log Bank Rate raw

Inflation expectations gap	8.575*** (2.491)	Observations	99
GDP	2.89 *** (0.977)	Adjusted R-squared	0.231

Standard errors in parenthesis.* significant at 10%; **significant at 5%; ***significant at 1%.

We learn from this model that the NRR for the Euro Zone is 2.34%. I would contend that this is a better model for the estimation of the NRR due to a higher adjusted R squared and much better significance of the variables and indeed the model as a whole. These results were confirmed by the t and F tests, with P values less than 0.05, therefore strongly rejecting the null hypothesis that coefficients are no different from zero. The coefficient for the inflation expectation gap cannot be interpreted in the same way, to imply the level of hawkishness, as the Taylor Rule. However, we are not surprised to learn that if the inflation expectation gap increases by one unit, we expect the bank set rate to increase by 8%, in an attempt to realign expectation. It is important to note that this does not mean an 800 basis point rise in the rate, but an 8% increase on its current absolute percentage value. This seems reasonable. Again, I would not overstate the importance of the GDP growth rate, aside from the fact that we expect its increasing one unit has a 2.89% upwards effect on the nominal interest rate set.

The Determinant Model

The Determination Model for the Euro Zone was stumbled across when trying to define the NRR Model. It was found that the exchange rate and unemployment level were insignificant to the model. The following initial specification was obtained:

$$\underset{(0.07)}{\text{logi}} = -0.62 + \underset{(1.14)}{2.56}(\text{INF}) - \underset{(0.04)}{0.22}(\text{STOXX}) - \underset{(0.58)}{1.41}(\text{GDP}) + \underset{(0.05)}{1.28}(\text{logBANKRATE}) - \underset{(0.07)}{0.63}$$

Log Nominal Rate raw

HCIP	2.561**	Observations	92
	(1.144)		
Stoxx	-0.22***	Adjusted R-squared	0.87
	(0.44)		
GDP	-1.42**		
	(0.576)		
Log Bank Rate	1.284***		
	(0.054)		

Standard errors in parenthesis.* significant at 10%; **significant at 5%; ***significant at 1%.

The intercept of this model cannot be interpreted as the NRR due to the fact that the dependent variable is no longer the bank rate. We learn that for a one-unit increase in the inflation rate, the nominal interest rate is expected to increase by 2.56%. For a one unit increase in the stock indices, the nominal interest rate trends downwards 0.2%. We are concerned to learn that for a one-unit increase in the GDP growth rate, the nominal interest rate is expected to decrease by 1.42%. If the *absolute* bank set rate increases by 1 basis point, then the nominal interest rate experiences a related increase of 128 basis points.

It was found that the model was statistically improved upon with the addition of a dummy variable, GDPINC (for GDP) that captures the upward or downward pressure on the nominal interest rate of a positive or negative output gap. If a positive output gap is present then upward pressure should be placed on the interest rate, where ‘1’ is set to be positive and ‘0’ otherwise.

Log Nominal Rate raw

HCIP	2.048*	Observations	92
	(1.093)		
Stoxx	-0.22***	Adjusted R-squared	0.88
	(0.042)		
GDPinc	0.07***		
	(0.023)		
Log Bank Rate	1.315***		
	(0.053)		

Standard errors in parenthesis.* significant at 10%; **significant at 5%; ***significant at 1%.

Our Adjusted R squared has improved, as has the significance of the GDP variable. The direction of the GDP coefficient has improved to act with the expected sign, whereby increasing GDP (and hence a one unit positive output gap) is manifested in an increase of 0.07% of the nominal interest rate. We see that monetary policy remains the majority determinant of nominal interest rates.

Specific Analysis of the Models

We know that for an OLS model to be accepted, a number of conditions must be met and tested to follow the Gauss-Markov framework.

Linearity and Normality: The relationships between the predictors and the outcome variables should be linear. The variables and the residuals resulting from the regression should all follow normal distributions.

Linearity tests were performed on each explanatory variable. When a deviation from linearity was found, a 'gladder test' was run again to ensure that the identity variable follows a closely normal distribution. Kernel density estimates were also generated on the models.

Running Shapiro-Wilk tests for normal data for these models yield the following output:

Variable	Obs'	W	V	Z	Prob>z
r	92	0.987	0.993	-0.015	0.506

We can deduce that, since the null hypothesis cannot be rejected at the 5% level, the model must be normally distributed.

Hetroskedasticity: We require the residuals of the model to hold a homogenous variance in order to make any inferences. A graph of the residuals was plotted against fitted values and despite an ambiguous looking plot there appeared to be no convergence at either end. Statistical tests were run in order to draw a conclusion.

The NRR Model contains no heteroskedasticity, since the Breusch-Pagan test fails to reject the null hypothesis that homogenous variance exists.

Breusch-Pagan / Cook-Weisberg test for heteroskedasticity	
HO: Constant Variance	
Variables: fitted values of logbankraw	
Chi2 (1) =	0.64
Prob > Chi2	0.423

White's test and the Breusch-Pagan test seem to indicate that some form of heteroskedasticity may be present in our Determinant Model:

Cameron & Trivedi's decomposition of IM-test

	Chi2	Df	P
Heteroskedasticity	28.22	13	0.008
Skewness	3.9	4	0.42
Kurtosis	0.47	1	0.494
Total	32.59	18	0.019

Breusch-Pagan / Cook-Weisberg test for Heteroskedasticity	
HO: Constant Variance	
Variables: fitted values of WHAT	
Chi2 (1) =	6.98
Prob > Chi2	0.008

We correct by running a robust regression.

Log Nominal Rate raw

HCIP	2.048**	Observations	92
	(1.032)		
Stoxx	-0.22***	Adjusted R-squared	0.88
	(0.036)		
GDPinc	0.07***		
	(0.023)		
Log Bank Rate	1.315***		
	(0.048)		

Robust standard errors in parenthesis.* significant at 10%; **significant at 5%; ***significant at 1%.

Nothing has changed in the statistics of our model, other than that the coefficient for inflation has now become significant, suggesting that this homoskedastic regression has generated a far better model for the determination of the nominal interest rate.

Colllinearity

Successful models should be free of multicollinearity, in that variables should not be correlated with one another. The presence of such a problem could lead to overinflated R squares, making the model seem better than it is. By finding the *variance inflation factor* we can deduce whether this is an issue for us in our models.

The final NRR Model yields acceptable variance inflation factors:

Variable	VIF	1/VIF
GDP	1.14	0.879
Inflation expectations gap	1.14	0.879
Mean Vif	1.14	

The final Determinant Model, post correction for heteroskedasticity, carries the follows variance inflation factors:

Variable	VIF	1/VIF
GDPinc	1.23	0.815
Log Bank Rate raw	1.2	0.832
Stoxx	1.11	0.9
HCIP	1.03	0.97
Mean VIF	1.14	

We should accept multicollinearity at a VIF threshold of 10, and an inverse threshold of 0.1. For each model, we are within both, and can deduce that no multicollinearity is present.

A weak correlation test consolidates our discussion on heteroskedasticity.

PW Correlations	Bank Rate	HCIP	Inflation ex' gap	Employment	Stoxx	GDP	SDR
Bank Rate	1.0000						

HCIP	0.1507	1.0000					
Inflation ex' gap	0.4461	0.3860	1.0000				
Employment	-0.1069	-0.2713	-0.0392	1.0000			
Stoxx	0.2530	-0.0347	0.1918	-0.0045	1.0000		
GDP	0.3983	0.2410	0.3476	-0.2988	0.3454	1.0000	
SDR	0.1598	0.0046	0.0383	0.1665	-0.983	-0.0370	1.0000
Inflation ex' gap raw	0.1507	1.0000	0.3860	-0.2713	-0.0347	0.2410	0.0046
Output gap raw	0.3983	0.2410	0.3476	-0.2988	0.3454	1.0000	-0.0370
Log Bank Rate raw	0.9948	0.1425	0.4223	-0.1096	-.2342	0.3924	0.1607
Log Nominal Rate	0.8806	0.2200	0.3047	-0.1469	-0.0153	-0.2281	0.1721
	Inflation ex' gap raw	Output gap raw	Log Bank Rate raw	Log Nominal Rate raw			
Inflation ex' gap raw	1.0000						
Output gap raw	0.2410	1.0000					
Log Bank Rate raw	0.1425	0.3924					
Log Nominal Rate	0.2200	0.2281	0.9004	1.0000			

Model Specification

In order to make inferences about whether the models have been correctly specified we may run a linktest, which tests the overall model specification strength. We can also run the Ramsey RESET test for omitted variables.

For the NRR Model:

Log Bank Rate raw

Hat	2.635	Observations	99
	(2.629)		
Hatsq	-0.568	Adjusted R-squared	0.23
	(0.911)		

Standard errors in parenthesis.* significant at 10%; **significant at 5%; ***significant at 1%.

Ramsey RESET test using powers of the fitted values of Log Bank Rate raw

HO: model has no omitted variables	
F (3,93) =	0.27
Prob > F	0.847

For the linktest we were unable to reject the null hypothesis that the model was correctly specified, at the 5% level. For Ramsey's RESET test, we were unable to reject the null hypothesis that the model contains omitted variable bias, at the 5% level.

Tests for the Determinant Model lead to ambiguous results:

Log Nominal Rate

Hat	-0.417	Observations	92
	(1.009)		
Hatsq	-0.203	Adjusted R-squared	0.884
	(1.755)		

Standard errors in parenthesis. * significant at 10%; **significant at 5%; ***significant at 1%.

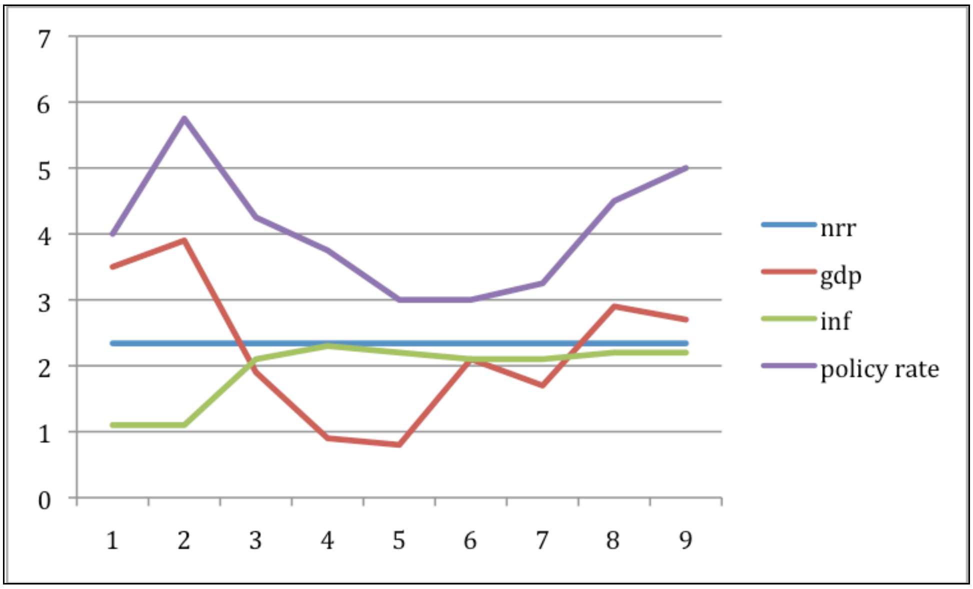
Ramsey RESET test using powers of the fitted values of logiraw

HO: model has no omitted variables	
F (3,84) =	13.62
Prob > F	0.0000

It seems that the model is specified correctly, yet seems to be missing variables. We are not surprised to learn this knowing that there are many more determinants of the interest rate on top of these. Some measure of either velocity of money in the respective economies or a measure of money supply might be very useful to this model if the question were to be asked again.

CONCLUSIONS AND EXTENSIONS

Using the models specified we have managed to deduce that the neutral real rate for the Euro Zone in the decade following monetary union on 1999 was 2.34%. The GDP growth rate for this period generally signified 'positive' output, so it is not surprising that the policy rate remained above the estimated NRR for the period as an attempt to control the possible overheating that was in progress. We can see also that the inflation rate needed control. The following plot begins with 1 = 1999, with the respective rates on the y axis.



The models that were generated have undergone a series of tests of their integrity. We have deduced that a lower R square is acceptable in our NRR Model. Through corrections for heteroskedasticity and the introduction of a dummy variable for GDP we have created a significant model with strong explanatory power for determining the nominal interest rate in the Euro Zone. The determinant model has too many variables for NRR determination, so we found the happy balance in our NRR Model where the NRR is not eaten into by non-parsimonious variables.

With further testing and data the accuracy of this research could perhaps be boosted. Firstly the assumption of static expectations is far reaching. However if inflation expectations could be generated, based upon a true maximisation problem and hence rational expectations, we would be better off.

Furthermore, I would propose that in reality, the NRR does shift over time and that a more in depth study of the period could be done by looking at the evolution of a rate over time using monthly data for each year.

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Data Sources

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